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interests which affect a large proportion of their population. In the west the great through-line starts in some of the busiest industrial centers of the world. In the east it taps coveted markets. The attention of European manufacturers is directed towards densely populated India or China simply because people spell trade.

L. D.

KRÜMMEL'S HANDBOOK OF OCEANOGRAPHY: A REVIEW*[1]

By **LUDWIG MECKING, Ph.D.**
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Modern oceanography dates from the middle of the last century. At that time an American naval officer, M. F. Maury, published the first comprehensive treatise on the "physical geography of the sea" and became the leading spirit in urging investigation of the sea and its phenomena. As a result of his efforts and in consequence of the awakening interest in marine zoology and the requirements of cable laying, numerous deep-sea expeditions were sent forth during the sixties, culminating during the seventies in the cruises of the *Challenger, Gazelle,* and *Tuscarora.* It was the extensive material collected on these trips which was then, in the eighties, scientifically sifted and summarized in a German handbook of oceanography by Boguslawski and Krümmel.

Since then a quarter of a century has passed. In that time the investigation of the sea has developed uninterruptedly. Krümmel himself took an active part in it on the German expedition of the *National.* But during the last quarter of a century, as compared with the preceding twenty-five years, the emphasis lay rather on intensive than extensive research, and rather on investigations of a theoretical than of a practical nature. Methods and instruments, due to the contributions of Nansen, Krümmel, Pettersson and others, have made notable progress. Special problems arose which required detailed study of restricted areas. On the coast of North America, for instance, it was the complicated phenomena of the tides which for years occupied the attention of the Canadian Department of Marine and Fisheries. In the marginal seas of Europe the need of a rational economic treatment of the organic resources of the sea has led to international co-operation on a large scale for the study of the North European seas, an example recently followed for the Mediterranean.

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* Translated from the original, written in German for the *Bulletin.*

[1] O. Krümmel: Handbuch der Ozeanographie. Vol. I: Die räumlichen, chemischen und physikalischen Verhältnisse des Meeres, 1907. (2nd edit. of Vol. I of "Handbuch der Ozeanographie," by G. von Boguslawski, 1884). xvi and 536 pp. Maps, diagrams, and tables. Vol. II: Die Bewegungsformen des Meeres—Wellen, Gezeiten, Strömungen, 1911. (2nd edit. of Vol. II of "Handbuch der Ozeanographie," by O. Krümmel, 1887). xvi and 766 pp. Maps, diagrams, tables; and index to both volumes. In series: Bibliothek geographischer Handbücher, begründet von Friedrich Ratzel: Neue Folge, herausgegeben von Albrecht Penck. J. Engelhorn, Stuttgart.

To do justice to this many-sided progress was the task of the new edition of the handbook, an undertaking now carried out by Krümmel alone. Indeed, no one else would have been as qualified as he, since for a generation he had been a leader in the science.

The content has been completely changed. Numerous new computations have been made; an enormous amount of material has been added and remodeled; theories have been tested and disputed questions cleared up; new conceptions and classifications have been established, new points of view gained and new problems formulated. The history of development, the relevant methods and instruments are also discussed under each section. Occasionally, even biological and anthropogeographical relations are referred to. More frequent reference is made to climatological and geomorphological influences. But the physical phenomena themselves always constitute the main theme. These phenomena are both treated in detail regionally and their general laws deduced. The source references are copious; the arrangement and treatment of the subject matter is clear.

The first volume is divided into three parts: (1) the ocean basins; (2) the bottom deposits; and (3) the waters of the ocean. The second volume is also divided into three parts: (1) the waves; (2) the tides; and (3) the currents.

The Ocean Basins. For the respective area of land and water Krümmel presents the new values of 148,800,000 sq. km. and 361,100,000 sq. km., *i. e.,* a ratio of 1:2.43. This section is, for instance, also prefaced by a historical summary in which are reviewed the conceptions as to distribution of land and water since Homeric time. The subdivision of the water surface of the globe leads to the establishment of three great oceans,—a conception already previously advocated by the author. The Arctic Ocean is thus considered only as an appendage of the Atlantic; the Antarctic Ocean is divided up among the three oceans. The representation of the southern hemisphere on Steinhauser's star projection or a glance at a globe clearly demonstrates the validity of this view. With rare depth of insight the author has established an entirely original classification, in which not only origin, but also position, size, shape, water content and movement are duly considered. The result is a natural system of the oceans. The main categories of subordinate seas [*Nebenmeere*] are the mediterranean seas and the marginal seas. The former are subdivided into intercontinental, or large, the latter into intra-continental, or small seas. The four large mediterranean seas are the Eurafrican, the American, the Australasian and the Arctic. The four small mediterranean seas are Hudson Bay, the Baltic Sea, the Persian Gulf, and the Red Sea. The most typical marginal seas are found on the western border of the Pacific. On the other hand, Krümmel's definition of "ingressional seas" and "faulted basins" [*Einbruchsmeere*] is open to criticism, inasmuch as it reverses the original meaning of "transgressional seas" and "ingressional seas" as introduced by Penck. Krümmel further subdivides the subordinate seas according to their horizontal articulation, their openness, insulosity, salinity (supernormal, normal, subnormal), temperature, and currents (whether independent of or dependent on the oceanic circulation). Similarly, the gulfs or bays and the straits are classified according to position, shape and origin.

The chapter on the surface of the sea deals with the different factors which cause deformation of the sea-level. One hundred meters is given as the maximum amount. The periodic and aperiodic fluctuations amount to only a few meters. The wind is the most general and potent cause of the latter. The reference to the designation of sea-level on nautical charts is important for studies and measurements on such charts. The customary indication is not to mean sea-level but to some stage of low water, differing with each nation. American charts are based on mean low water; British and German, on the low water of the spring tide; French, again, on the lowest recorded stage.

A chapter on deep sea soundings reviews in detail the various types of apparatus, their development, construction and source of errors.

Very important and in a great measure new is the chapter on the general morphology of the ocean bottom. New conceptions are put forward, such as "critical angle of slope," "rhythm of submarine relief," "mean trough width and depth," which define the degree of submarine relief numerically. For the Atlantic between 0° and 47°

N. a mean angle of slope of 0° 27′ 44″ is determined. The regions of especially steep slope are enumerated in a list containing the names of 37 isolated submarine volcanic peaks. The author has also computed the zonal apportionment and the area covered by the various depths. The tropics and subtropics have the greatest proportion of depths over 4,000 m. In the classification of the forms of submarine relief Krümmel follows Supan's well-known suggestions (*Petermanns Mitt.,* 1903). The shelf areas and the characteristic peculiarities of their relief are discussed in detail. The area and elevation of the various shelfs are also given; there is likewise a list of oceanic troughs (22 in number) with their maximum depths. This list is, however, no longer complete, as particularly during the last few years the German surveying vessel *Planet* has discovered many new troughs or sounded known ones more completely. The stated maximum depth of the sea, 9,636 meters, has also become obsolete since the new sounding of 9,788 meters in the Philippine Trough by the *Planet* three years ago. The mean depth of the sea, based on a new computation, is given as 3,680 meters and the volume of ocean waters as 1,330,000,000 cubic kilometers. Nearly half of this volume lies between the tropics. The values for the land block and the water block should also be revised, since Meinardus has demonstrated a surprisingly high mean elevation (2,000 meters) for the Antarctic Continent. The revised values are already given, for instance, in Wagner's *Lehrbuch der Geographie.*

The Bottom Deposits. While an older classification by Murray and Renard distinguishes only between terrigenous and pelagic deposits, Krümmel adds an intermediate type, the hemipelagic deposits. The first group (termed by Krümmel the littoral deposits) he subdivides into shore deposits and shelf deposits. The intermediate group (hemipelagic) consists of blue mud, red mud, green mud, volcanic mud and coral mud. The third group (eupelagic deposits) embraces the five well-known types of ooze: globigerina, pteropod, diatom, radiolarian, and red clay; these are further classified according to their character. The properties and horizontal distribution, the extent and vertical distribution of each deposit are discussed in great detail and illustrated by tables, illustrations and text-maps (on an equal-area projection).

The Waters of the Ocean. In this, the longest section of the first volume, the new material available through international co-operation is utilized very fully. Krümmel also makes use of modern physical chemistry with remarkable thoroughness and applies it in all its varied relations to the waters of the ocean as a "dilute solution" (possibly more correctly: a mixture of many dilute solutions). Boiling point, osmotic pressure, evaporation, surface tension, viscosity, compressibility, electrical conductivity and radio-activity are all discussed. Much more space is devoted, however, to salinity and gas content, density, optical properties and especially to temperature. A new definition is given of salinity which will tend to simplify observational methods. All constituent elements of sea-water and their most important combinations are indicated. The total amount of salt is computed to be 48,400 trillion tons. The relation of river salt to sea salt is discussed, together with the origin of the latter. The surface salinity is indicated of each of the subordinate seas and, by five-degree zones, of the oceans. As regards the vertical distribution of salinity, Krümmel distinguishes a number of types (homohaline, anohaline, katohaline, mesohaline, dichohaline), on the basis of which the general distribution of salinity, particularly in the subordinate seas, and its seasonal variations are discused. On the open sea, the most remarkable phenomenon is a minimum of salinity at about 800 meters' depth in all southern waters, as first discovered by the *Gauss.* This is due to an undercurrent from the Antarctic. The density of sea-water at various temperatures is given in a table; also the density maxima for varying degrees of salinity. Transparency and color are dwelt upon at length, from the point of view of absorption as the fundamental principle. The relations to depth of water and clouding by terrigenous and planktonic material are taken up. No cartographic representation is attempted of the distribution of color of sea-water (an excellent map of this type for the Atlantic accompanies G. Schott's *Geographie des Atlantischen Ozeans*). The section on the gases in sea-water is based mainly on the comprehensive material dealing with the European marginal seas, while for the main body of the ocean the older data of the *Challenger* expedition are exclusively used, as the valuable material from the *Gauss* and *Planet* cruises was not yet available. An absorption table is given for oxygen and nitrogen. The function of nitrogen as the regulator of the wealth of organic life is interestingly discussed in the final chapter, based on the original investigations of the zoologist K. Brandt on sea-water as the source of food for pelagic plant life. To be sure, these represent only an initial and still uncertain step into the difficult field of the metabolism of pelagic organisms. Indeed, Gebbing's later researches on the *Gauss* do not seem to agree with these theories.

Heat is transmitted to sea-water mainly by the sun, only to a minimal extent by the interior of the earth. In the thermal conditions of the sea, in contrast with those of the land, wave and current motion and particularly vertical convection are of great importance. The latter subject could not be treated as comprehensively as the subsequent investigations of Nansen on the bottom water in the northern seas might allow. The mean surface temperature has been computed by Krümmel for each ocean by ten-degree zones. The mean surface temperature proves to be 3° C. warmer than the lowest stratum of air over the whole earth; the seas of the northern hemisphere, again, are 3° C. warmer than those of the southern, this predominance of greater warmth in northern waters even holding good for the corresponding zones in both hemispheres; the Pacific Ocean is 2.2° warmer than the Atlantic. A new conception is that of the ''individual temperature variation.'' This is defined as the variation of temperature undergone by a water particle moving forward in a current. As regards the vertical distribution of temperature the same types are recognized as for salinity. A map of the horizontal distribution at a depth of 400 meters shows how the equatorial surface belt of maximum temperature is split into two subtropical maximum belts enclosing a belt of relatively minimum temperature. This phenomenon increases with increasing depth and is explained by Krümmel as due to the existence of vertically descending currents and a lateral depression of the warm water of the equatorial currents. The sub-surface temperatures of the northern seas are discussed in special detail. Broad perspectives are opened up by the brief discussion of the mean temperature of oceanic waters, which has been computed for the first time by ten-degree zones, and of the thermal interchange between sea and air. Finally the last chapter is devoted to the ice phenomena of the ocean, from the processes of the formation and transformation of ice to the laws governing its distribution.

The Waves. Waves are first considered as to their dimensions and their properties in deep and shallow water, using the trochoidal theory as a basis. Its formulæ are then tested by means of observed and measured instances, including measurements by photogrammetry, and are found to conform well for deep water. The origin of waves Krümmel explains, after giving an historical survey of older theories, according to Helmholtz's law. He then discusses the growth of waves with a continuous wind, the relation of wave velocity to wind velocity, the evolution of the ground swell from the wind-created wave, and the factors causing the extinction of a wave. Among these factors inner friction is of small consequence as compared with lateral expansion, newly developing wind-created waves, breakers on the coast or extraneous objects like drift-ice, rain or snow and oil. The discussion of the surf gives the author opportunity to illuminate problems of coastal physiography, on which occasion the power of wave action is ably analyzed from the oceanographical standpoint. Coastal shifting due to along-shore erosion (Philippson's ''Küstenversetzung'', for which Krümmel suggests ''Strandvertriftung'') Krümmel ascribes to the same cause, wave erosion, as do modern physiographers. Such abnormally large waves as earthquake waves, etc., Krümmel attributes in the majority of cases to tectonic origins, while the seismologist Rudolph considers them predominantly of volcanic origin. Considerable space is devoted to standing waves, or seiches, whose widespread occurrence also along sea coasts is becoming more and more known. Finally, the first connected account is given of the phenomenon of internal waves, to which students of hydrodynamics and oceanography (Ekman, Nansen) have only recently devoted attention. These are waves which are formed on the tangential surface of two moving layers of water of different density and velocity.

The Tides. No phenomenon of the sea is so hard to demonstrate in a simple, not too mathematical and yet thorough way as the tides. Krümmel first defines the various concepts relating to tides, then discusses the methods of measuring them, and finally develops the theory of tides, beginning with the equilibrium theory and proceeding through the various dynamic theories to harmonic analysis. In spite of the age of the equilibrium theory (Newton) and the general acceptance of its principles, new attempts are constantly being made to express it clearly and accurately, but in a simple mathematical form. Much less securely established are the dynamic theories, which attempt, on the basis of the former, to interpret mathematically the multiplicity of terrestrial phenomena. Of these the most important rival theories are the standing wave theory of Ferrel and Harris and the canal theory of Airy and Börgen. Krümmel rejects Harris's theory with its division of the ocean into separate and independent oscillatory regions and on the whole gives preference to the canal theory as developed by Börgen. In a chapter on tidal currents the most important section is a very clear explanation of rotatory currents. Many examples of tide action in river estuaries are discussed. After all these abstract and rather physical chapters there follows an extended and strictly geographical account of the regional distribution and individual characteristics of the tides along the various coasts of the ocean and its arms. Special emphasis is laid on the latter, particularly those of the North Atlantic and of the Australasian Mediterranean. For the high seas and even for the coasts of the open ocean the observational records are still very incomplete. Krümmel nevertheless attempts a broad synthetic characterization for the Atlantic Ocean on the basis of the values for the establishment of the ports, but at the end he confesses resignedly: "For the time being everything is still as if enveloped in fog."

The Ocean Currents. The methods of observing currents are first discussed, from the determination of leeway displacement and the instruments employed—their increasing use is only of recent date—to the drift-bottles, natural drift objects and indirect evidences (temperature, salinity, plankton). Computational methods are also discussed, especially those for current direction and current stability. Then follow the theory of currents and finally the description of existing oceanic circulation. The theoretical discussion is based on the assumption that the wind is the primary causative agent, however no longer according to Zöppritz, who did not take into account the effect of the earth's rotation, but in modified form according to Ekman's new mathematical investigations. According to this theory, a surface current, however long the wind may blow, cannot be transmitted to an unlimited depth but, rather, disappears at a relatively short distance from the surface. This depth, at which the direction of the surface current is changed into the contrary by the earth's rotation and its velocity nearly consumed by friction, is known as the "frictional depth" [*Reibungstiefe*]. Krümmel terms the factors affecting a current "current constituents" and divides them into active, or primary, and passive, or secondary. This division in itself is very important and corresponds to the facts, but the terms "constituent factors" and "modifying factors" would seem more appropriate. The theoretical investigations which attempted to determine quantitatively the deflectional influence of the rotation of the earth are confirmed to a certain extent by several statistical studies which, by comparing the direction of the wind and of currents, determined the angle of deflection in various seas (Arctic Ocean, Baltic Sea, Mediterranean Sea, Indian Ocean). These values average 45°. Another modifying factor, the configuration of the coast line, leads to distinguishing between "forced," independent and compensatory currents. Instead of the wind theory of ocean currents various others have recently been suggested (Nansen, temperature; Pettersson, ice-melting) which are all more or less based on density compensation. Krümmel evaluates this factor correctly in according it only a secondary position as a current-producing agency. Currents due to density compensation are represented, on the one hand, by the cold bottom water which, with its polar beginnings, constitutes one section of a great but slow vertical current system and, on the other hand, in straits which connect basins of different density. Such are the Strait of Gibraltar and the sounds between the North and Baltic Seas; in the former case, the subordinate sea (Mediterranean) has the denser water, in the latter case it (Baltic) has the less dense. While in these theoretical discussions reference is rarely made to the actual conditions of the ocean, the survey of the ocean currents in the last section is constantly correlated with the preceding theoretical expositions, so that here the attempt is first made to bring theory and observation into coincidence or to explain the natural phenomena by means of the theory.

The section on currents alone occupies one-quarter of the whole work and possibly represents the most important advance in oceanographic science. It also best reveals Krümmel's masterly gift to hew a path through a chaos of new material and from the rough stones not only to erect a homogeneous edifice but also to keep a lookout from every one of its vantage-points, to open up new vistas and to discover gaps.

AN INTERPRETATION OF THE DISTRIBUTION OF THE REPTILES IN MAGGIE BASIN, NEVADA

By ALEXANDER G. RUTHVEN

In a recent paper[1] on the reptiles and amphibians of Maggie Basin, in northeastern Nevada, it was shown that the distribution of the species of these groups apparently corresponds closely with the distribution of certain environmental conditions chief of which are the presence of water, the nature of the soil and the presence of rocks. Since the distribution of the species is thus associated with physiographic features, it may be expected to exhibit characteristics due to changes in the geographical cycle and thus to be open to a more complete interpretation from this point of view. It is the purpose of this paper to discuss the effect of the geographical changes upon the habi-

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[1] The Reptiles and Amphibians collected in Northeastern Nevada by the Walker Newcomb Expedition of the University of Michigan. By Alexander G. Ruthven and Helen Thompson Gaige. *Univ. of Mich. Museum of Zool. Occ. Papers No. 8.*